(11) (A) No. 1 185 435

(45) ISSUED 850416

(52) CLASS 53-243

(51) INT. CL.[4] C22B 21/02

(19) (CA) **CANADIAN PATENT** (12)

(54) Fume Recovery System in the Carbothermic Production of Aluminium

(72) Sood, Raman R.;
Southam, Frederick W.;
Dewing, Ernest W.,
Canada

(73) Granted to Alcan International Limited
Canada

(21) APPLICATION No. 398,905

(22) FILED 820319

No. OF CLAIMS 10

Canada

A B S T R A C T

In the carbothermic reduction of alumina evolved carbon monoxide has a high content of Al fume and Al_2O. A substantial part of this fume is recovered by allowing the temperature of the CO gas to fall by 50-150°C during passage through a moving bed of carbon particles at a temperature of 50-150°C. The carbon particles move through the bed in either co-current or counter-current direction in relation to the CO gas and such bed may be retained in an enclosure which is rotatable about a vertical axis to a body of molten alumina, which lies beneath it. Solid alumina may also be introduced into the carbon particle bed. This is conveniently done by introducing the alumina particles into the top end of the bed with a downwardly flowing CO gas stream.

"IMPROVED FUME RECOVERY SYSTEM IN THE CARBOTHERMIC PRODUCTION OF ALUMINIUM"

The present invention relates to the carbothermic reduction of alumina to produce aluminium metal and in particular to an improved method and apparatus for recovery of fume generated in carbothermic reduction processes.

The reduction of alumina with carbon is highly endothermic and only proceeds to the production of aluminium metal (in the absence of other reducible oxides) at temperatures in excess of 2050°C. The production of aluminium metal at these very high temperatures is accompanied by evolution of very large volumes of carbon monoxide.

Many different proposals for carbothermic reduction of essentially pure alumina have been put forward and some practical success has been obtained.

Thus in U.S. Patent No. 2,974,032 a reaction mixture of carbon and alumina was heated from above with an open arc from carbon electrodes at a temperature in excess of 2400°C.

In U.S. Patent No. 3,783,167 it has been proposed to produce aluminium by carbothermic reduction of alumina in the plasma of a plasma furnace.

In U.S. Patent No. 4,099,959 a molten alumina slag, containing dissolved aluminium carbide, is circulated successively through a zone of relatively low temperature, in which carbon feed material is added to the slag to react with the alumina to augment the aluminium carbide content of the slag, and a zone of relatively high temperature in which aluminium carbide reacts with alumina to release aluminium metal which is collected and separated from the slag, the aluminium carbide content of the slag being simultaneously reduced. The slag from the high temperature zone may

be returned to the preceding low temperature zone in a 2-vessel system or it may be forwarded to a succeeding low temperature zone in a multi-vessel system. Alumina is supplied at a suitable location, preferably a high temperature zone, to replace the alumina consumed in the process.

In all the above-mentioned processes and, indeed, in any process involving carbothermic reduction of alumina, the actual production of aluminium metal involves an operating temperature in the reaction zone (or final reaction zone) of at least 2050°C and usually higher. At such high temperatures the partial pressures of Al vapour and Al_2O, aluminium suboxide, are substantial and these components back-react with the evolved carbon monoxide as the gas temperature is lowered. Such back-reaction is highly exothermic and represents a very large potential loss of energy. Furthermore, it gives rise to the formation of deposits of aluminium oxy-carbide, which are sticky and tend to block up gas conduits.

In U.S. Patent No. 4,099,959 the reaction in the low temperature zone may be represented as

$$2\,Al_2O_3 + 9C \longrightarrow Al_4C_3 \text{ (in solution)} + 6CO$$

whereas the reaction in the high temperature zone may be represented as

$$Al_4C_3 \text{ (in solution)} + Al_2O_3 \longrightarrow 6Al + 3CO$$

These reactions are both highly endothermic and proceed at temperatures within the ranges of about 1950° - 2050° and 2050° - 2150°C respectively. The temperatures in the low temperature zone(s) and the high temperature zone(s) are accordingly held within the above specified temperature ranges.

The large volumes of gas released in the low temperature zone(s) and in the high temperature zone(s)

carry substantial quantities of fume (both Al metal vapour and aluminium suboxide, Al_2O). The amount of fume carried by the evolved CO is however considerably greater in the gas evolved in the high temperature zone than in the gas from the low temperature zone because of the higher temperature and consequently higher vapour pressure of Al and Al_2O.

In U.S. Patent No. 4,099,959 these fume components are removed from the evolved gas by passing the gas through the carbon feed material prior to introduction of the feed material to the low temperature zone and contact with carbon is clearly applicable for fume removal from carbon monoxide evolved in any carbothermic process for production of aluminium from alumina. It is an object of the present invention to allow back-reaction of the fume components to proceed under controlled conditions which avoids the formation of massive deposits which lead to blockages. It is a further object of the invention to allow back reaction to take place under such conditions that at least a part of the heat released in exothermic back reactions is recovered in a form directly relevant to the carbothermic reduction process.

In accordance with the present invention the back reaction takes place in a moving bed of carbon particles held at a temperature in the range of 1950 - 2080°C. In one arrangement the gas is brought into contact with solid alumina in such bed, the solid alumina being converted to molten alumina which is then introduced into the carbothermic reduction reactor system. The solid alumina is in one alternative supplied to the top of the packed

bed of carbon particles. A molten alumina slag, containing dissolved aluminium carbide, flows out of the bottom of the packed bed.

As an alternative to supply of alumina to the top of the bed, a part of or all the solid alumina, preheated if desired, can be fed into the molten slag in the region of the bottom of the reactor. In a further alternative, a part of or all the alumina may be injected directly in the form of solid particles into the fume-laden gas stream before entry to the bed.

The gas may be progressed counter-current or co-current to the flow of alumina slag in the packed bed, which is preferably subjected to mild agitation to prevent the formation of channels in the packed bed, and/or formation of solid bridges between the components of the bed and/or the bed and the wall. Since carbon is consumed in the scrubbing procedure (additional to the carbon formed by back-reaction of aluminium values (Al vapour and Al_2O) with carbon monoxide) additional carbon is supplied to the bed as well as the solid alumina feed. Some at least of the additional carbon is preferably in the form of coarse particles of a size typical of the particles of the packed bed to make good losses from the bed in operation.

The scrubbing procedure is preferably carried out in a two-zone reactor, which comprises a somewhat tapering base section, to act as a collector for the molten slag and an upper section, preferably generally

cylindrical, mounted on the base section and free to move about its vertical axis in relation to the base section. The upper section then houses the packed bed, which at its bottom end is supported by the downwardly tapering wall of the base section and the pool of molten slag collected therein. The upper section may be continuously or intermittently rotated or oscillated about its vertical axis to effect mild agitation of the packed bed. The base section is preferably stationary but may in some circumstances be rotated or oscillated while still providing some relative movement with respect to the upper section.

The scrubbed gas issuing from the reactor and still containing a minor proportion, for example 25%, of its fume content, is preferably forwarded to a heat recovery stage in which a circulating stream of cooled alumina is heated by heat exchange with the gas and back-reaction of the remaining fume with CO, part of the thus heated alumina being passed to and cooled in a heat-recovery, steam-raising boiler stage.

The solid alumina feed for the two-zone reactor is drawn from the circulating stream of alumina and the carbon requirement for the scrubbing procedure is, at least in part, introduced with this alumina. By correct control of the temperature reduction of the gas, as it passes through the scrubbing stage and the heat recovery stage, it would be possible for the

carbon deposited in the alumina in the heat recovery stage to be rather exactly matched with the carbon feed requirement of the scrubbing stage. Make-up cold alumina feed is supplied to the circulating alumina stream in the heat recovery stage and small quantities of carbon may also be introduced into this feed or directly into the two-zone reactor of the scrubbing stage if required.

The fume-free, but still hot, gas issuing from the heat recovery stage is then forwarded to a carbon feed preheat stage, in which the carbon feed for the carbothermic reaction is preheated to a temperature in the range of 800 - 1000°C, for example.

In the scrubbing operation, in order to maintain the slag at a temperature above the "carbon line" in the phase diagram it is generally only permissible to reduce the gas temperature by about 50°C - 150°C depending upon slag temperature and composition during its passage through the two-zone reactor. However this permits about 75% or even more of the fume content of the gas to be recovered as Al_4C_3.

In feeding materials to the two-zone reactor alumina and carbon may be fed separately. The carbon, where fed separately from the alumina feed, is prefer-

ably fed into the top of the reactor in the form of coarse particles of approximately the same size as the particles of the packed bed. The alumina may be fed in either at the top of the reactor or at the bottom of the reactor (preferably entrained in the gas stream), or both.

The gas is conveniently led into the bottom of the reactor and is then preferably blown through the molten slag in the base section of the reactor. This entrains molten slag from the pool in the base section and this slag separates from the gas as it passes upwardly through the packed bed so that it trickles back through the packed bed as a counter-current flow in relation to the upward gas stream. Heat transfer from the gas to the alumina takes place to a large extent at the extended surface presented by the slag trickling downwardly counter-current to the ascending gas. Additional alumina is formed at higher levels in the packed bed by reason of back-reaction between the fume components and carbon monoxide and trickles in a molten state downwardly in the bed.

In this arrangement the solid alumina feed and the carbon feed to the 2-zone reactor may conveniently be effected by being pneumatically injected into the conduit conveying the gas to the two-zone reactor.

Where the packed bed scrubber is operated in this way, there is a tendency for the packed bed to become flooded when the gas throughput per unit area of the bed rises above a critical level at which the frictional drag on the downflowing slag counteracts the gravitational force on the slag.

In order to avoid the requirement for an excessively large diameter packed bed in the upper section of the reactor when very large gas flows are to be treated, it may be desirable to introduce the

fume-laden gas into the top of the two-zone reactor. In such case the alumina feed and carbon feed materials are also introduced into the top of the reactor so as to move co-current with the gas flow.

When this co-current mode of operation is employed considerably higher gas flow rates are acceptable or a smaller vessel for the same flow rate.

The packed bed in the scrubber reactor is arranged in an entirely conventional manner for the contact of a stream of liquid with a counter-current or co-current flow of gas.

The particle size of the bed is selected to provide an extended gas/liquid contact surface and a relatively low resistance to gas flow (whether upward or downward). The equivalent diameter of the carbon particles supplied to the packed bed is in the range of not more than 1/10 of the bed diameter down to 20 mm.

The "particle equivalent diameter" may be defined as the diameter of a sphere with the same surface area as the average particles at the top of the bed.

The upper section of the scrubber reactor, in which the packed bed is contained, is preferably constructed with a very slightly larger diameter at the bottom end than at the top end so as to permit the downward movement of the carbon particles of the packed bed under the mild agitation applied to the bed, such movement being necessary because of the slow consumption of the coarse particles of the bed in the operation of the bed. The increase of diameter should preferably be sufficiently small to avoid the formation of inadequate packing at the lower end of the upper section between the bed and the surrounding wall. It is preferred that the slope of the wall of the upper section is of the order of 2 - 5 mm per metre (0.2 - 0.5%).

The upper section of the scrubber reactor is preferably constructed with a steel outer shell, lined with a layer of thermal insulation and having a carbon refractory inner lining. The thermal insulation is arranged to maintain the heat loss at a low value but is preferably arranged so that there is a small controlled heat loss sufficient to maintain the temperature at the inner face of the lining at such value as to be below the "carbon line" in the phase diagram so as to minimise erosion of the carbon lining by attack by molten alumina.

As already explained the packed bed is formed of coarse carbon particles. These particles are preferably formed of appropriately sized, coarsely broken calcined petroleum coke of a grade employed for the production of carbon electrodes. This coke presents less available area for reaction than coke feed particles supplied to the scrubber reactor mixed with or separated from the alumina feed. However, as already stated, part of the carbon supplied to the scrubber reactor is usually in the form of sized particles to replace losses from the packed bed.

In a further development of the invention, the packed bed for recovery of fume values is arranged above the low temperature chamber(s) of a two-

zone carbothermic reduction system of the type described in U.S. Patent No. 4,099,959 with the result that alumina in a molten state enters the molten slag in the chamber and the carbon, required to replace carbon consumed in the carbothermic reduction reactions, enters the slag already preheated to a temperature almost equal to the temperature of the slag in the low temperature chamber.

In a further alternative method of putting the invention into effect the back reaction is allowed to take place in a packed carbon bed which consists wholly of or in part of "active" carbon, so that a substantial part of the Al and Al_2O fume content is converted directly to Al_4C_3. "Active" carbon for the present purpose can be considered to be any form of carbon possessing a large specific surface area and consequently a relatively low strength, so that the resulting Al_4C_3 reaction product does not adhere strongly to the carbon particles and/or is very porous and open, so that the deposition of the reaction product does not result in cementing of the carbon particles to one another.

In this alternative a small amount of alumina slag is also deposited in the carbon bed, but it is not the purpose of this alternative to generate molten alumina for introduction into the carbothermic reduction reactor. Therefore preferably there would not also be an addition of solid alumina to the bed, although in some instances it might be convenient to introduce some solid by means of a scrubber system as already described above.

The carbon drawn off from the bottom of the packed bed scrubber may be fed directly to the carbothermic reactor as feed or it may in some instances be preferred to pass it to a cooler. The cooled carbon may then be ground and employed as feed for the carbothermic reduction reactor without further treatment. In many instances, however, it is preferred for the carbon feed rate to the packed bed scrubber to be in excess of the feed rate of carbon required by the reactor. In such case the collected carbon is classified after grinding and the fine fraction is employed as feed. A major part of the deposited Al_4C_3 is normally found in the relatively fine feed material.

According to a further aspect of the invention deposition of solids in the conduit or conduits leading to the scrubber reactors is reduced or avoided by generation of heat in the gases passing through the conduit or conduits and/or by dilution of the gases to reduce the partial pressure of Al fume and Al_2O in the gas. In most instances carbon dioxide or water (either as liquid or steam) is injected into the gas stream as it enters the conduit leading from the reactor to the packed bed scrubber. This serves both as a diluent and as a mild oxidant, which converts the Al vapour to Al_2O. Alternatively heat may be generated in the conduit by injection of carefully controlled small quantities of oxygen which are intended to produce sufficient heat to make good the heat loss from the conduit so that the gas stream enters the packed bed scrubber at substantially the same temperature as it left the reactor.

The prevention of formation of deposits in an outlet conduit from a carbothermic reactor by dilution and/or oxidation of the fume content of the gas is of general application and is not confined to the method of the present invention in which the fume-laden gas is cooled in contact with a moving packed bed of carbon particles.

Referring now to the accompanying drawings,

Figure 1 is a diagram of a complete fume and heat recovery system for a carbothermic furnace for aluminium production.

Figure 2 is a diagrammatic representation of a two-zone scrubber reactor for counter-current flow.

Figure 3 is a diagrammatic representation of a two-zone reactor arranged for co-current flow.

Figure 4 shows the partial phase diagram for the system Al-O-C.

Figure 5 is a diagrammatic representation of the scrubber of the present invention positioned above a low temperature chamber of a carbothermic reactor system.

Figure 6 is a diagram of a further form of fume recovery system in accordance with the invention.

In the accompanying Figure 1 there is illustrated

diagrammatically a complete system for the recovery of thermal and chemical energy from fume-laden CO off-gas from a carbothermic furnace for the production of aluminium.

In Figure 1 gas from the carbothermic furnace is led through a conduit 1 at a temperature of the order of 2030-2050°C (in this example). At that temperature the fume content of the gas in one typical example is 35 - 40% by weight and is composed of Al vapour and Al_2O in the ratio of approximately 1:6. The efficient recovery of the chemical and thermal energy represented by this fume content is therefore extremely important in relation to the economical performance of the carbothermic reduction of alumina to aluminium metal, as is also the efficient recovery of the sensible heat and chemical energy of the emitted CO gas.

The initial treatment of fume-laden gas is performed in scrubber reactor 21. In the counter-current mode of treatment gas enters the bottom of the reactor and exits from the top as indicated diagrammatically in full lines in Figure 1. In the co-current mode the gas enters the top of scrubber reactor 21 and exits from the bottom as indicated in dotted lines.

In the counter-current mode the gas from conduit 1 enters scrubber reactor 21 (as shown in Figure 2) and is bubbled through a pool 22 of molten slag contained in a stationary base section 23 of said reactor. The gas, in emerging from the slag pool 22, throws up molten slag into the lower part of a packed bed 24 of coarse carbon particles housed in an upper section 25 of the reactor 21 as already described. The gas passes up through the packed bed 24 and emerges through an axial exit passage 26. The alumina and carbon feed requirements of the system may be supplied via a port

26a above the packed bed or may be injected pneumatically through a passage 27 into the incoming gas stream in conduit 1 or may be divided between these two routes.

The gas, exiting from the two-zone scrubber reactor, is at a temperature of 1950 - 1980°C and flows through conduit 2 to a venturi feeder reactor 28. The gas, which still has a substantial fume content, is brought into contact with a much larger mass of relatively cool solid alumina in reactor 28. The alumina, which already contains a proportion of carbon, is heated by heat exchange with the gas by, for example, 1000°C in reactor 28. Alumina and carbon are formed by back-reaction of the remaining fume content with carbon monoxide.

The gas with entrained alumina is forwarded from venturi reactor 28 through conduit 29 to cyclone 30. The separated alumina, containing about 5-10% carbon, is led out of cyclone 30 through conduit 6. The required amount of alumina for feeding the scrubber reactor 21 is supplied to that reactor through conduit 3 and constitutes about 25-30% of the alumina led out from the cyclone 30. The remainder of the hot alumina is led through conduit 8 to a heat exchange boiler 31, in which it gives up heat to raise steam. The cooled alumina from boiler 31 is forwarded through conduit 10 to a mixer 32, in which it is mixed with cold make-up feed alumina, together with a small amount of make-up carbon feed, entering through conduit 9 and is then recirculated through conduit 5 to the venturi reactor 28.

In the foregoing description of the recovery of heat from the off-gas from the scrubber reactor 21 it is assumed that the alumina/carbon ratio of the alumina issuing from cyclone 30 through conduit 6 has been

arranged to be that required for supply to the scrubber reactor 21. If the alumina/carbon ratio is not that required for reactor 21, additional alumina or carbon is supplied to that reactor to correct the ratio and where additional alumina is required, then there will be an increase of the proportion of the circulating alumina stream diverted to the reactor 21. In many instances it will be preferred to introduce coarse make-up carbon feed particles direct to reactor 21 to make good losses from the packed bed.

The cooled CO gas issuing from cyclone 30 is essentially free from fume components, but still has a high sensible heat content, which is employed to pre-heat the carbon feed to the carbothermic furnace.

The gas from cyclone 30 is led through conduit 7 to a venturi reactor 33 in which it is contacted by cold feed carbon entering through conduit 11. The carbon is heated to 800 - 900°C by contact with the gas and is forwarded via conduit 12 and is separated from the gas in a second cyclone 34, from which it is led to the carbothermic furnace through conduit 14.

The carbon heated in this system usually constitutes in excess of 95% of the total carbon input to the carbothermic furnace, the remaining carbon feed introduced through conduit 9 or directly into the scrubber reactor 21 being forwarded to the furnace in the form of Al_4C_3 as part of the Al_4C_3 content of the slag which collects in the base section 23 of the reactor 21. This collected slag is returned to the carbothermic furnace through conduit 4.

The CO gas stream from the cyclone 34 is passed through a conduit 13 to a gas cleaning unit 35, from whence it is passed to a gas holder via a conduit 15.

As already explained, it is an important feature of the method of the invention that the packed

bed in the reactor 21 is preferably subjected to mild agitation to break up bridges that may be formed between the carbon particles forming the bed and to maintain the bed in a substantially homogeneous condition to avoid channelling, which could lead to local overheating of the bed along the channels. Such agitation also aids heat transfer between the gases and the slag. For this reason in the construction of the reactor 21, shown in Figure 2, the stationary base section 23 is somewhat tapered to contain a pool 22 of molten slag, which, together with the inclined wall of tapered base 23, supports a packed bed 24 of carbon particles. The base section is provided with a gas inlet 40 to admit gas from the conduit 1 and a slag outlet port 41, leading to conduit 4, into which a gas inlet 42 is preferably provided to permit introduction of an inert gas, such as argon, to drive slag through conduit 4 to the carbothermic furnace.

In Figure 2 the upper section 25, which is essentially cylindrical in character, is supported by a radially projecting flange 44 of the lower section. The upper section 25 is rotated, either continuously or intermittently, or oscillated by two or more drive rolls 45, symmetrically arranged around the upper section 25.

In order to provide a gas-proof seal between the rotatable upper section and the stationary lower section, the shell of the upper section is provided with a flange 46, parallel to the flange 44. A measured stream of inert gas is introduced under pressure through orifices 47 so as to purge furnace gases from this region. A layer 48 of powdered graphite is maintained above the flange 46 to act as a gas seal to prevent outflow of gas.

Figure 3 shows a modified construction of scrubber reactor intended for co-current operation. In Figure 3

like parts are indicated by the same reference numerals as in Figure 2.

In the construction of Figure 3 both the fume-laden gas and the feed material are introduced through an axial top-opening 26', so that the feed and the gas travel co-current downwardly through the packed bed 24. The gas is discharged through a series of ports 50 in the wall of the upper section 21 into a gas manifold 51, secured to the casing of the stationary lower section 23. Gas is discharged from manifold 51 via one or more outlets (not shown) to venturi reactor 28.

At the top of the manifold 51 a gas-proof seal is provided between a flange 52 carried by the casing of upper section 21 and a corresponding flange 54 at the top of the manifold.

As already explained the co-current arrangement allows faster gas flow rates through the packed bed without flooding the bed and therefore a smaller scrubber apparatus may be employed to handle a given gas flow. The apparatus is both cheaper to construct and may be operated with a lower overall heat loss because a smaller area of carbon lining is required to be maintained at a temperature below the "carbon line". On the other hand, counter-current flow provides better gas-slag contact and therefore more efficient scrubbing. Since the counter-current reactor is necessarily larger, the pressure drop across the reactor vessel will be less.

In operating the device in either co-current or counter-current mode it is only necessary to rotate the upper section a few times in an hour in order to obtain the required movement of particles in the bed to avoid channelling and bridging.

The described system ensures that a substantial portion of the chemical energy due to the fume content and the sensible heat of the off-gas from a carbothermic reduction furnace is recovered in the form of Al_4C_3 and molten alumina to supply to the materials additions chamber of a carbothermic reduction system as for example described in U.S. Patent No. 4,099,959. It also enables the carbon feed for such a system to be preheated to a substantial extent towards reaction temperature.

By virtue of the supply of a large part of the required Al_4C_3 and by virtue of supply of molten alumina and preheated carbon feed to the materials additions chamber of a system of the type described in U.S. Patent No. 4,099,959 the heat input requirements of such chamber are very much reduced.

In the operation of this system of the present invention increase in the feed of alumina to the scrubber reactor results in increased cooling of the gas and increased reaction in the scrubber reactor. However if the feed rate is excessive the temperature goes below the carbon line so that the reaction product is not Al_4C_3, but only alumina and carbon. On the other hand, if the temperature of the bed goes too high, the proportion of the fume which is converted to Al_4C_3 in the reactor decreases. Consequently it is preferred to control the alumina feed rather carefully to ensure that the packed bed conditions are only slightly above the carbon line.

In one example of an efficiently operated scrubber treating the fume content of the off-gases from a carbothermic furnace having an output of 1 tonne Al/hr the dimensions of the packed bed are 1.6 metres diameter and 4.5 metres high when operated in the counter-current mode. In the co-current mode the required dimensions are 1.3 metres diameter and 4 metres high.

The incorporation of the fume recovery system of the present invention into a carbothermic reaction system of the type described in U.S. Patent No. 4,099,959 is illustrated in Figure 5.

In the apparatus of Figure 5 the system incorporates a low temperature reaction chamber 61 and a high temperature reaction chamber 62, connected by a forward slag duct 63 and a return slag duct 64, which preferably includes means for controlling the electrical resistance of the slag stream therein as described in our co-pending Patent Application No. 2011475.

The slag, composed of molten alumina and dissolved aluminium carbide, is circulated through the system formed of chambers 61 and 62 by generation of gas in the forward duct 63 as a result of heating the slag in duct 63 by electric resistance heating. For this purpose electrodes 65 and 66 are respectively provided in chambers 61 and 62.

The gas generated by the reaction of Al_4C_3 and Al_2O_3 to release Al in duct 63 and chamber 62 is returned from chamber 62 to chamber 61 by gas return duct 67, which enters chamber 61 above the level of molten slag, but as close to that level as is practicable. The gas from chamber 62 becomes mixed with the gas generated in chamber 61 in the lower part of the column 68, formed by feed materials in a scrubber upper section 69 of the chamber 61.

The scrubber section 69 is constructed in a manner similar to the scrubber illustrated in Figure 3, except that the gas duct 67 from chamber 62 enters the manifold 51 so that the gas flows upwardly through the column 68 countercurrent to the descending feed material, of which the column 68 is composed.

In this arrangement the feed to the column 68 is composed of Al_2O_3 and C in proportions required by the process, taking into account the relevant proportions of the alumina, which will be carried out as Al and Al_2O in the exhaust gas exiting from the upper section 69.

The feed to column 68 can consist of a mixture of carbon and alumina intimately mixed as pellets. Alternatively the feed may consist of individual pellets of Al_2O_3 and carbon lumps.

Successful execution of the proposed scheme requires that the feed be properly sized to avoid channelling and hot spots in the column, and excessive pressure build up in the carbothermic reduction furnace formed by chambers 61 and 62.

During the upward passage of the gas through the packed bed column 68, liquid slag is liable to be carried into the upper regions of the column. Liquid slag is also produced due to scrubbing reactions. The liquid slag percolates downwards unless the bed becomes flooded, as explained above. The dimensions

of the chamber 1, particularly of its inverted conical upper part, are selected to avoid flooding in the column.

Control of composition of the slag is achieved by lining chamber 61 with a graphite or other suitable carbon lining 70 to act as a counter electrode to central electrode 65 and passing current from the central electrode 65 to this lining. Heat can thus be imparted to the contents of zone 61 where carbon is available, increasing the formation of Al_4C_3.

The major beneficial aspects of the system of Figure 5 are

(a) Recovery of Al values from the carbothermic furnace fume on to the feed material that is being continuously fed to the furnace.

(b) Efficient preheating of the feed in a counter current manner by the fumes from the reduction furnace. Such counter current preheating is highly energy efficient.

(c) Efficient scrubbing of any fine particulate matter formed by back reactions in the fumes. Packed bed scrubbing is known to be an efficient process for removal of fine solids.

(d) Self regulating feeding mechanism as the charge moves downwards at a rate equal to its consumption.

In the system shown in Figure 6 a carbothermic reduction reactor is indicated diagrammatically at 71. The stream of gas generated in the reactor 71 is led through a conduit 72 to a scrubber 73.

One or more gas jets 74 lead into conduit 72. Mildly oxidizing steam or CO_2 may be supplied through the jets 74. Alternatively the jets may be hydrocarbon-mantled oxygen jets.

The scrubber 73 may consist of a stationary base part 75 and a rotatable upper part 76, operating on the general principles of the apparatus of Figures 2-3 to keep the carbon particles in motion.

The conduit 72 conveys gas to the stationary manifold 77, from which it enters the upper part 76 through ports (not shown). The gas flows up the reactor and is led out axially through a conduit 78 to a further treatment stage, illustrated diagrammatically at 79. The gas stream typically undergoes a temperature reduction of 50-150°C during its upward progress through the carbon bed in the scrubber 73 countercurrent to the descending carbon particles in the upper part 76. During descent aluminium carbide is formed by reaction of the Al vapour and Al_2O with the active carbon particles in the packed bed.

The carbon particles are withdrawn at controlled rate from the scrubber 73 by means of a rotatable extractor 80 and discharged to a cooled storage unit 81. The cooled carbon from the unit 81 is preferably passed through a grinding stage (not shown) to a classification stage 82, from which a coarse fraction, composed of carbon and some Al_4C_3, is returned via conduit 83 to the upper end of the scrubber 73. "Active" carbon, preferably preheated, is introduced via conduit 84 in an amount sufficient to balance the rate of feed carbon (containing Al_4C_3) via conduit 85 from the classification stage to the reactor 71.

1. A method for the treatment of fume laden carbon monoxide from a carbothermic reduction of alumina which comprises introducing the carbon monoxide gas into a moving bed of carbon particles held at a temperature of 1950-2080°C and allowing the temperature of such gas to fall by 50-150°C during passage through said bed.

2. A method according to claim 1 in which such gas is passed through said bed of carbon particles in a counter-current direction to the moving carbon particles.

3. A method according to claim 2 in which said carbon particles consist wholly or in part of active carbon particles.

4. A method according to claim 1 in which said moving bed of carbon particles is maintained above a body of molten aluminous slag.

5. A method according to claim 4 in which said bed of moving carbon particles is maintained in an enclosure which is rotatable about a vertical axis in relation to a container for said body of molten aluminous slag.

6. A method according to claim 5 in which solid alumina particles are supplied to said moving bed of carbon particles.

7. A method according to claim 6 in which said solid alumina particles and said fume-laden carbon monoxide gas is introduced into the top end of said moving packed bed and progressed co-current through said packed bed.

8. A method according to claim 7 in which said carbon monoxide is withdrawn radially outwardly near the bottom end of said packed bed and molten alumina is withdrawn downwardly from said packed bed into said body of molten aluminous slag.

9. A method according to claim 6 in which said fume-laden carbon monoxide is introduced through said body of molten aluminous slag for upward flow through said moving bed of carbon particles.

10. A method according to claim 9 in which solid alumina particles are injected into the fume-laden carbon monoxide stream before entry into said body of molten aluminous slag.

Fetherstonhaugh & Co.,
Ottawa, Canada
Patent Agents

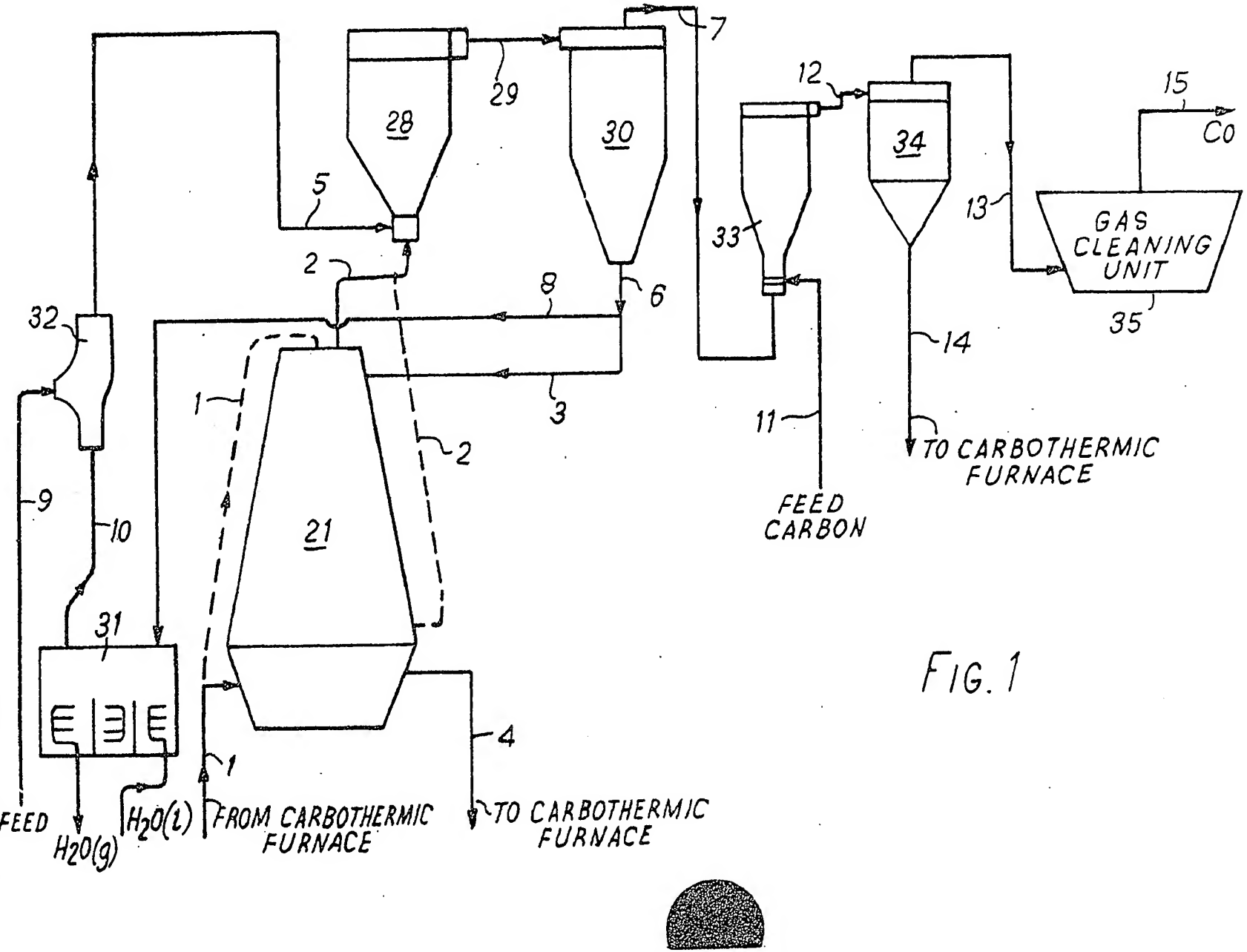
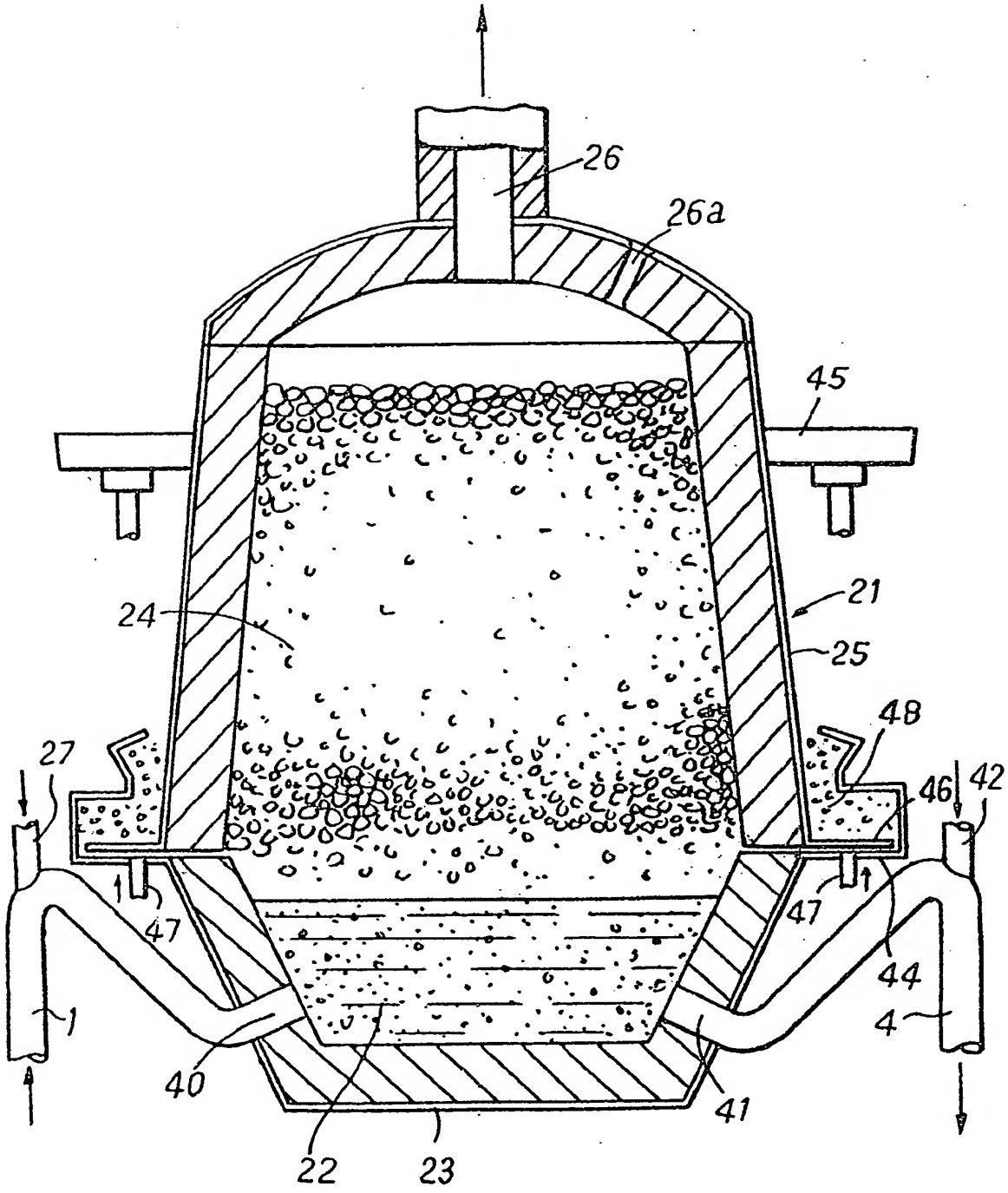


FIG. 1

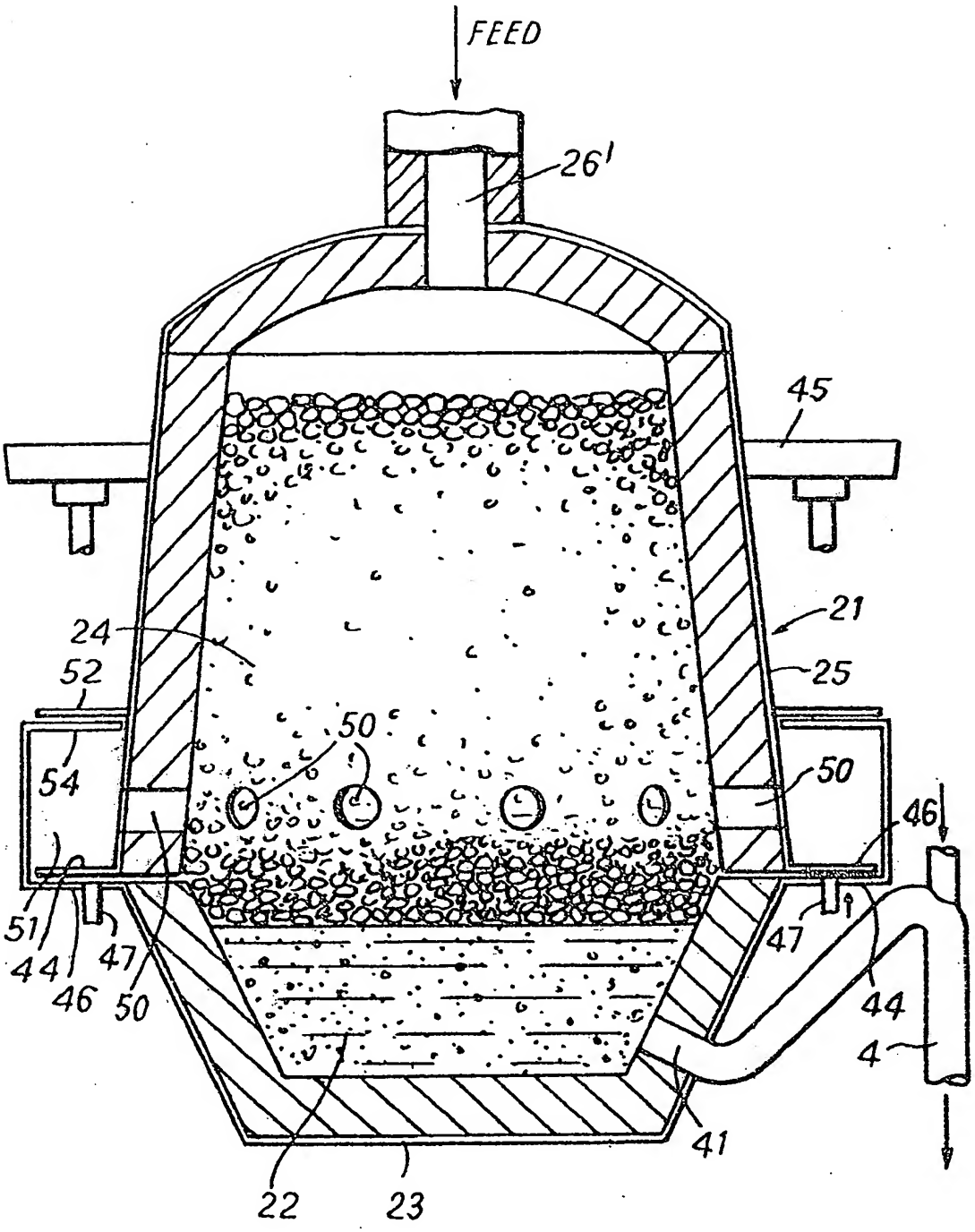
Patent Agents
Fitzpatrick & Co.

FIG. 2



Patent Agents
Fitzpatrick & Co.

FIG. 3



Patent Agents
Fetherstonhaugh & Co.

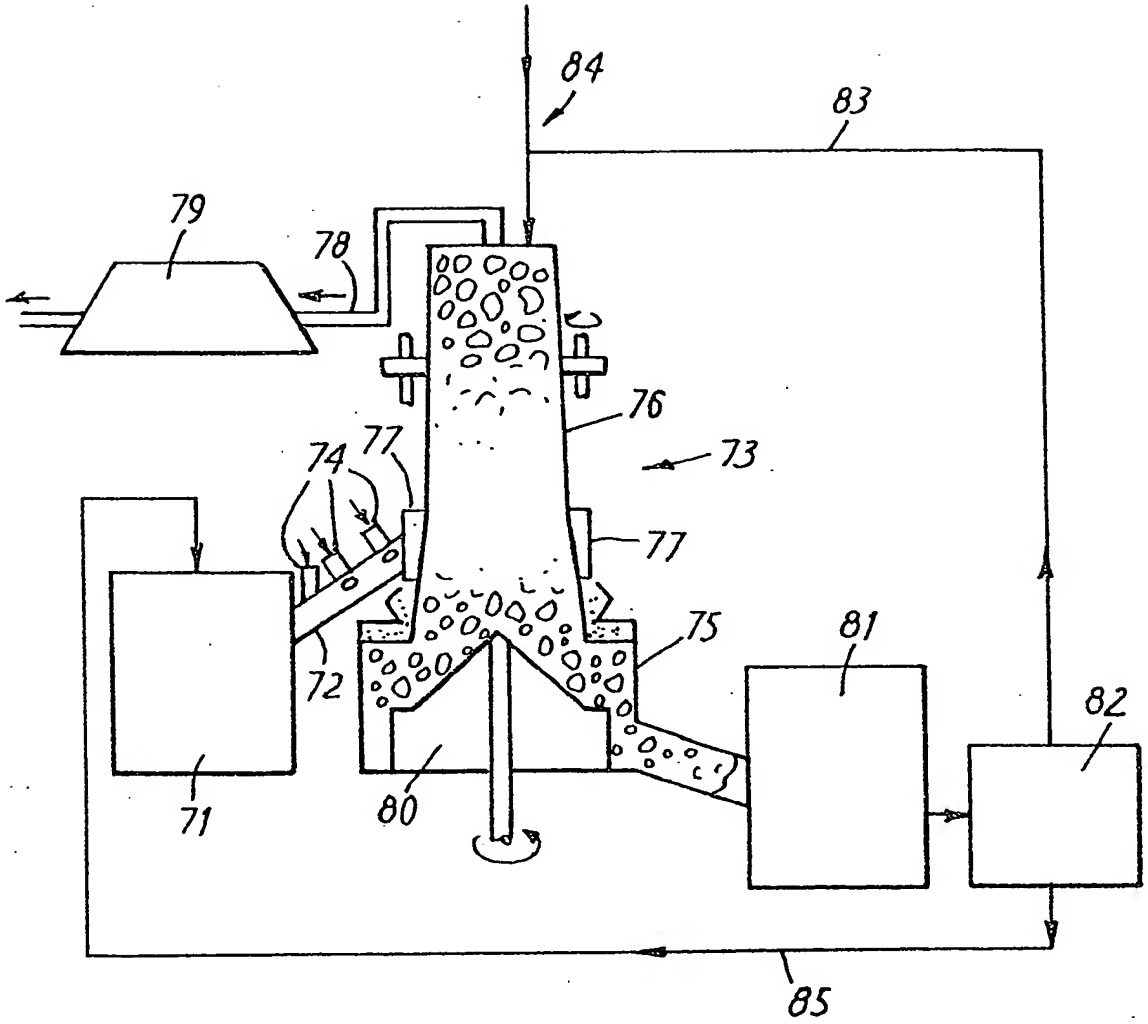


FIG.6

Patent Agents
Fitzpatrick & Co.

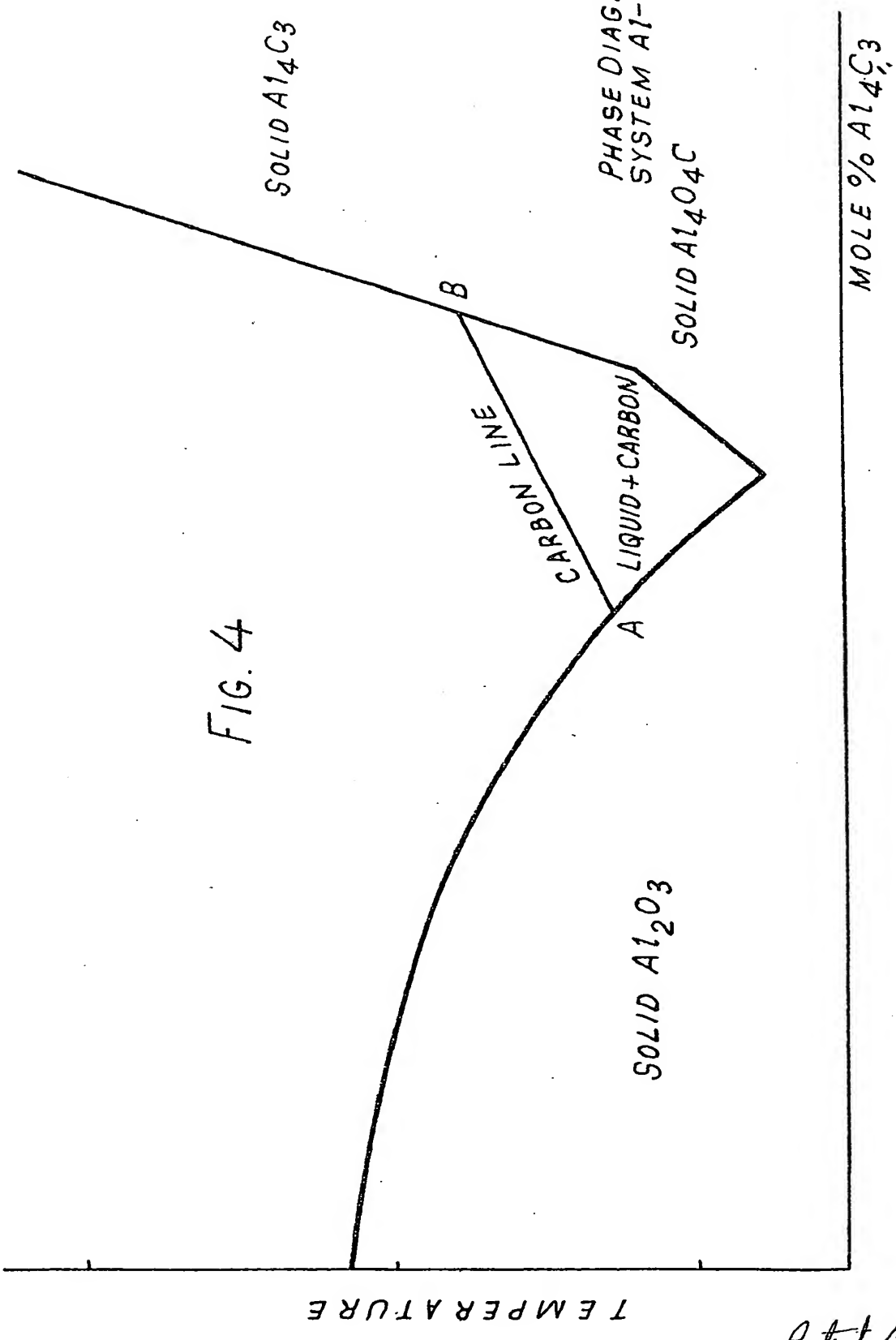


FIG. 4

Patent Agents
Fetherston haugh + Co.

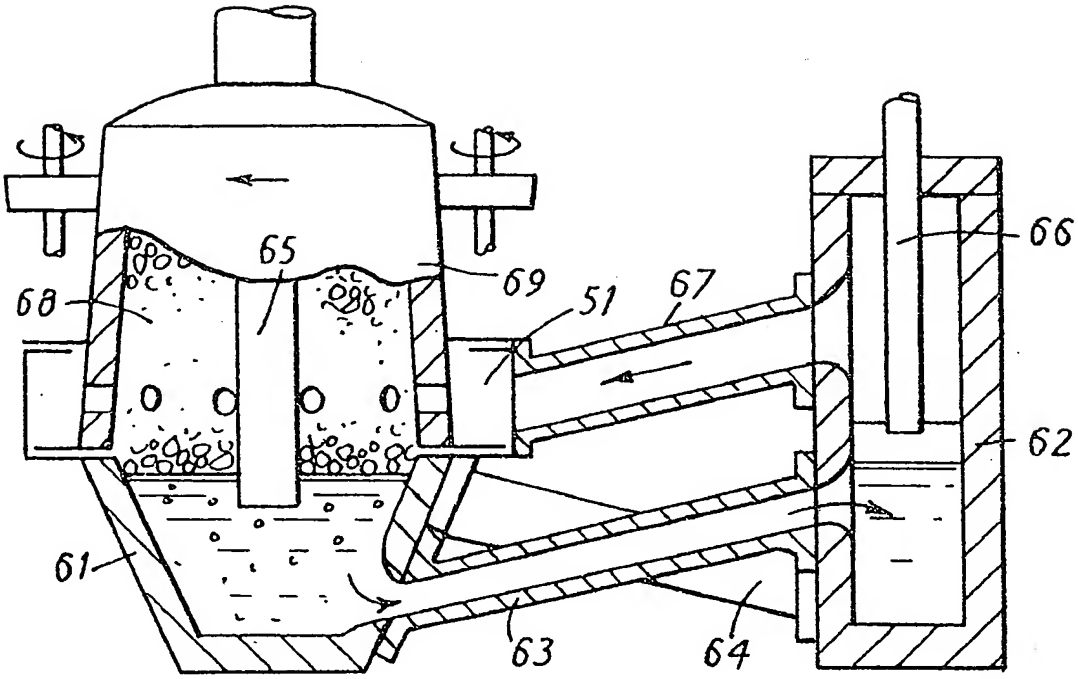


FIG. 5

Patent Agents
Fetherstonhaugh + Co.